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AN INVESTIGATION INTO SIMPLE METHODS OF REDUCING

THE TEMPERATURE IN TARPAULIN COVERED STORES

Gerald L. Long*, John A. McRae and Barry T. Murrell

The work reported in this Technical Note was jointly carried out at the Joint Tropical Trials and Research Establishment, Innisfail and Materials Research Laboratories, Maribyrnong.

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ABSTRACT (12) 15

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AN INVESTIGATION INTO SIMPLE METHODS OF REDUCING THE TEMPERATURES IN TARPAULIN COVERED STORES

1. INTRODUCTION

In the design of military materiel, account has to be taken of the environmental conditions that the materiel is likely to encounter throughout its service life. It is accepted that the highest environmental temperatures are experienced by materiel stored in the open under tarpaulin covers [1,2]. Similar temperatures are found close under the roof in railway vans exposed to the sun [3,4].

The climatic factors affecting the design of military materiel are the subject of a Quadripartite Agreement, QSTAG 360, "Climatic Environmental Factors Affecting the Design of Military Materiel", between the Armies of the United States, United Kingdom, Canada and Australia and this agreement specifies the design limits for maximum storage temperatures that can be expected under tarpaulin covers in the hot/dry areas of inland Australia. A tarpaulin-covered stack of ammunition boxes has been used to characterise the storage environment of both hot/dry and hot/wet areas of Australia [5].

It seemed probable that quite simple variations of the standard storage configuration of a closed, tarpaulin-covered stack could be used to reduce the temperatures inside the stack. It was therefore decided to monitor the temperatures inside empty ammunition boxes while varying the configuration and covering of the stack. These experiments were conducted at the Joint Tropical Trials and Research Establishment site at Cloncurry, Queensland, which is representative of much of the hot/dry inland area of Australia covered by QSTAG 360, Climatic Category A2 [6,7].

2. EXPERIMENTAL

The work was carried out in four periods of 4-5 days each between July 1976 and July 1977. These were the periods of the three-monthly inspections of the unattended Cloncurry exposure site.

Empty, painted steel ammunition boxes (0.48 m x 0.20 m x 0.9 m high) were stacked six layers high, with ten boxes in each layer, on a wooden pallet resting on concrete blocks 0.1 m thick. Each stack was covered by a standard olive-drab tarpaulin made from proofed, cotton-polyester, corespun duck (mass 500 g/m^2). Unless otherwise specified the tarpaulin was wrapped round the stack, tied with a rope about 0.5 m above the ground and the edges weighted with concrete blocks to prevent air flow under the stack. This was the configuration of the reference stack (Fig. 1b).

For the first three series, five type T (copper-constantan) thermocouples were suspended in the air in boxes at the north-east and north-west top corners and on the south side of the stacks in the bottom row, in the fourth layer from the top, and in the layer one from the top. In the fourth series of experiments when three stacks arbitrarily labelled A, B and C were used, similar thermocouples were positioned in the north-east and north-west top corners and the centre of the south side at the bottom of the stack. The voltages from the thermocouples were recorded on paper tape by a multichannel data logger at 10 minute intervals for the first three series and at 5 minute intervals for the fourth series. The system was calibrated and the temperatures measured were accurate to better than ± 0.5°C.

Five basic stack treatments were used. These were :-

(1) The boxes in the stack were spaced about 50 mm apart (Fig. 1a).

(2) The tarpaulin was lifted so that there was a 0.1 m air gap under the stack (Fig. 1c).

(3) An extra pallet was placed on top of the boxes to provide a 0.15 m air gap between the top of the stack and the tarpaulin (Fig. 1d).

(4) Single-sided, aluminium foil-paper laminate was used to cover the stack under the tarpaulin (Fig. 1e).

(5) The tarpaulin was supported away from the stack by a light metal frame on top of an extra pallet, in the style of a tent (Fig. 1f).

In two further experiments treatments (3) and (4) were combined, with the foil-paper laminate covering only two sides and the top of the stack (Fig. 1g), and the tarpaulin was spread over the frame and tied to the ground all around the stack (Fig. 1h).

In the first three periods, the effects of one treatment were measured each day by comparing the temperatures in a reference stack with those in the experimental stack. In the final period, in June 1977, the two treatments (4) and (5) which had given the most significant reductions in temperatures in the first three periods, were compared with each other and with a reference stack. The experimental design is summarised in Tables 1(a) and 1(b).

TABLE 1(a)

STACK TREATMENTS IN THE FIRST THREE PERIODS

Day	Date	Reference Stack	Experimental Stack							
			Reference	Boxes Spaced	Air Gap	Extra Pallet	Foil-paper Laminate		Tent	
							4 Sides	2 Sides	Open	Closed
1	21 Jul 76	x	x							
2	23 Jul 76	x		x						
3	24 Jul 76	x				x				
4	14 Oct 76	x	x							
5	16 Oct 76	x					x			
6	17 Oct 76	x				x	x			
7	18 Oct 76	x			x	x	x			
8	19 Oct 76	x			x					
9	18 Jan 77	x				x		x		
10	19 Jan 77	x							x	
11	20 Jan 77	x								x

TABLE 1(b)

STACK TREATMENTS IN THE FOURTH PERIOD

Day	Date	Treatment		
		Reference	Foil-paper Laminate over Extra Pallet	Open Tent
1	13 Jul 77	Stack C	Stack B	Stack A
2	14 Jul 77	Stack B	Stacks A & C	-
3	15 Jul 77	Stack A	-	Stacks B & C
4	16 Jul 77	Stack A	Stack C	Stack B

3. RESULTS

The results from the first three periods are given in Table 2 where the mean ambient temperatures and the mean stack temperatures between 1000 hours and 1600 hours for all positions in reference and experimental stacks are shown for each treatment.

From the results in Table 2 it appeared that the most effective treatments were the foil-paper laminate over an extra pallet (days 6 and 7) and the open tent (day 10). These treatments were tested against each other in the fourth period and the results are shown in Table 3.

4. DISCUSSION

Empty ammunition boxes were used because, having a minimum thermal mass, they give the most sensitive measure of heat absorbance by the stack. The effects of having stores in a box would be to reduce the temperatures below those of an empty box and to slow down both the rise and rall of temperature by amounts depending on the heat capacity and thermal conductivity of the stores.

As stacks were prepared each morning and required some time for temperatures to stabilise, readings before 1000 hours were not used in the analysis. Readings taken after 1800 hours (approximately sunset) were also excluded from the analysis as they tended to obscure the effects produced during the day when solar radiation was heating the stack.

To overcome the problem of day-to-day variations in meteorological conditions, temperatures of the control stack were used as a reference and related to temperatures in the experimental stack by linear regression. After processing several days data, this method was found to be too insensitive to distinguish between the different treatments. The more effective

TABLE 2

MEAN TEMPERATURES FOR FIRST THREE PERIODS

Day	Treatment (refer Table 1a)	Figure	Mean Temperatures (°C)		
			Ambient	Reference Stack	Experimental Stack
1	Similar Stacks	1b	26.0	38.8	39.8
2	Boxes Spaced	1a	27.1	36.8	37.7
3	Extra Pallet	1d	25.8	37.1	35.0
4	Similar Stacks	1b	32.2	42.4	41.9
5	Foil Covering	1e	34.5	35.9	33.1
6	Foil Covering with Extra Pallet		32.1	35.1	28.8
7	Foil Covering with Air Gap		26.2	41.2	31.4
8	Air Gap	1c	33.3	43.9	43.8
9	Foil Covering 2 sides	1g	34.7	35.9	32.5
10	Open Tent	1f	35.2	46.6	35.9
11	Closed Tent	1h	33.8	38.4	34.0

TABLE 3

MEAN TEMPERATURES FOR THE FOURTH PERIOD

Day	Mean Temperature (°C)			
	Ambient	Treatment		
		Reference	Foil-Paper Laminate	Tent
1	23.8	43.1 (C)	35.3 (B)	27.6 (A)
2	24.2	39.2 (B)	31.6 (A)	
			34.1 (C)	
				24.4 (B)
3	21.4	35.6 (A)		26.0 (C)
4	17.2	33.6 (A)	28.5 (C)	20.5 (B)

treatments had 95% confidence limits of about ± 2°C in the top positions while the temperature differences between the treatments were of the same order.

The results from all four periods were therefore analysed using a "t" test to determine whether the means of the difference between the temperatures at corresponding stack positions at the same time of day were significantly different from zero, and by an analysis of variance to assess the significance of the stack position.

The "t" test showed that all differences in mean temperature were significant at the 0.01% level except for the treatment on day 8 where a gap was left for air flow under the stack, when the difference in temperatures was not significant at the 25% level.

The analysis of variance was calculated treating all temperatures recorded on each day as replicates [8]. The results showed that both treatment and stack position were responsible for significant temperature differences except on days 1, 4 and 8 when the treatment was not significant at the 10% level.

The results from the fourth period, when the two most promising treatments from the earlier periods were tested against one another, confirmed that the open tent was more effective in lowering stack temperatures than covering the stack with foil-paper laminate. The mean temperatures between 1000 hours and 1600 hours at the different stack positions are shown in

Table 4 where it can be seen that the open tent, which shades the stack from direct solar radiation while allowing free air flow, keeps stack temperatures within a few degrees of ambient air temperature.

TABLE 4

MEAN STACK TEMPERATURES (°C) FOR DAY 1 OF THE FOURTH PERIOD

Position	Stack Treatment		
	Reference	Open Tent	Foil-Paper Laminate
South Bottom	30.3	24.9	24.1
North-West Top	50.1	29.0	39.0
North-East Top	49.0	28.9	42.7
Means	43.1	27.6	35.3
	Mean Ambient Temperature 23.8°C		

The experiment was designed to study the effects of different treatments and the configurations that were used - small stacks, empty boxes and short periods of exposure - do not allow the actual temperatures to be related to those that would be experienced in real field storage situations. However there is no reason to suppose that the same treatments applied to an actual field storage stack, would not give a similar, significant reduction in temperatures.

One of the major limitations on experiments involving outdoor exposure of specimens is the inability to predict the meteorological conditions that will be encountered during the period of the experiment. Because of this, it has often been considered advisable to carry out relatively long-term experiments to ensure that a representative sample of meteorological conditions is experienced and that sufficient data are collected to allow valid conclusions to be drawn. This experiment has shown that, for comparative studies where different treatments are to be compared with a standard or control treatment, results can be obtained rapidly and with little effort if the experiment is appropriately designed and the collection of the data is efficient. This could have quite wide application in the design of outdoor exposure trials.

5. CONCLUSIONS

This study has shown that :

5.1 Temperatures in an exposed tarpaulin-covered stack can be significantly lowered by placing an extra pallet on top of the stack to provide an air gap between the top of the stack and the tarpaulin and at the same time keeping the tarpaulin away from the sides of the stack to allow a free air flow (Fig. 1f).

5.2 Placing foil-paper laminate between the tarpaulin and the stack with an extra pallet on top also gave a significant reduction of temperatures but was not as effective as the treatment under 5.1 above.

5.3 The experimental design and method of analysis gave significant results rapidly and with a minimum of effort.

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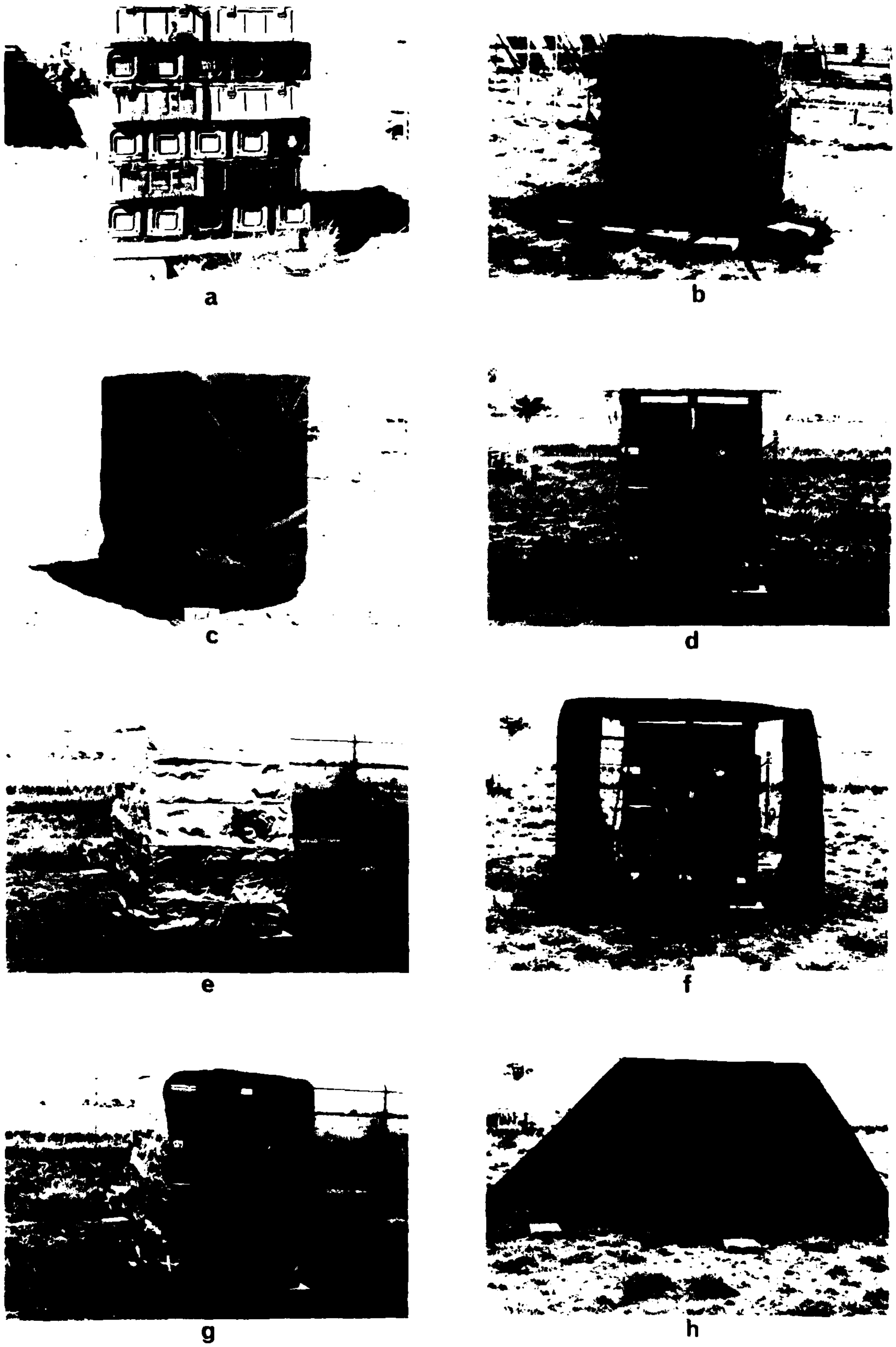

FIGURE 1. Stack Configurations

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